Storage Performance of *Gloriosa superba* L. as a Potential Cut Flower Species in Europe

M.P. Hettiarachchi  
Department of Crop Science  
Faculty of Agriculture  
University of Ruhuna  
Mapalana, Kamburupitiya  
Sri Lanka

J. Balas  
Institute of Fruit Growing & Horticulture  
University of Natural Resources & Applied Life Sciences  
Peter Jordan Street 82, A-1190  
Vienna  
Austria

Keywords: Postharvest quality, vase life, standard vase solution, chlorophyll fluorescence, flower colour, cold storage

Abstract

The effect of cold storage on the vase life and quality of freshly harvested cut flower stems of *Gloriosa superba* L. (Glory Lily/Climbing Lily) placed in Standard Vase Solution solutions was investigated. The vase life and fresh weight of *Gloriosa* inflorescences were significantly affected by storage temperature. A significant difference resulted between “dry” (inflorescences stored in polythene bags) and “wet” storage in a preservative solution ‘Standard Vase Solution’ (NaHCO₃ 125 mg/l, CaCl₂·2H₂O 99 mg/l, CuSO₄·5H₂O 1.2 mg/l introduced by van Meeteren et al., 1999) for flower quality features during vase life period. “Wet” storage (4 ºC for 7 d) of fully open *Gloriosa* flowers markedly improved flower keeping quality. Chlorophyll fluorescence values ($F_0$, $F_m$ and $F_v$) increased up to day 3 of vase period and then decreased over rest. Compared to other treatments, flowers kept at 4 ºC (“wet” storage) for 7 days maintained a higher photosynthetic yield (0.76) during vase period. There is a significant decrease of chlorophyll fluorescence yield with increased storage temperature. The CIE $L^*a^*b^*$ colour system (McGuire, 1992) was used to assess the colour of petals and leaves with a Chroma meter. There is a positive influence on $L^*$ (leaf lightness) and hue angle to longer vase life and fresh weight of flowers during vase period. However, there is no significant relationship of chroma value for vase life or fresh weight. Although visual quality could be maintained for up to 10 days in cold storage at 4 ºC, flower quality decreased notably after 7 days. Our results indicate that “wet” cold storage at 4 ºC for 7 days has the potential to be used for delaying inflorescence senescence, prolonging vase life and postharvest quality of *Gloriosa* cut flowers. *Gloriosa* is becoming an interesting floricultural crop in Europe. There is a potential to introduce it as a cut flower and as a potted plant to the international and European market.

INTRODUCTION

Introduction of new crops has recently become a major emphasis within the floriculture industry that produces, cut flowers, foliage and potted plants. There is potential for *Gloriosa* species to be commercially used as cut flowers or potted plants in Europe. The commercial success of any new cut flower depends on its aesthetic qualities, ease of production and vase life after normal commercial handling. Specific postharvest data is lacking for newly introduced cut flowers and therefore, growers, vendors, and florists face problems to organize flower marketing and distribution of high quality flowers to consumers. Storing of cut flowers in coolers benefits the grower, wholesaler, and florist by extending the production season, allowing storage of excess production, and enabling long-distance shipment (Goszczyńska and Rudnicki, 1988). This study was conducted to determine whether cold storage could be used for *Gloriosa* postharvest channel in hopes of expanding the market and enable long-distance transportation. Vase life was evaluated based on colour changes and flower and leaf senescence.
MATERIALS AND METHODS

In the summer periods of 2001 and 2002, the planting was established in a green house that belongs to University of Natural Resources and Applied Life Sciences, Vienna, Austria. Rhizomes of micro-propagated plants were obtained from a commercial source, planted three per pot in large plastic containers (30 cm (L) × 30 cm (W) × 30 cm (D)), using ‘Torboflor’ standard substrate mixture + Perlite (4 : 1 ratio), and placed in the plant house. Fully opened flowers were harvested with two to three leaves, immediately placed in clean tap water filled buckets. Then flower buckets were transported to the institute laboratory. There, the stems were trimmed to a length of 15 cm prior to subject in experiments and again they were placed in fresh tap water.

Standard Vase Solution (SVS) introduced by van Meeteren et al. (1999), (NaHCO$_3$ 125 mg/l, CaCl$_2$·2H$_2$O 99 mg/l, CuSO$_4$·5H$_2$O 1.2 mg/l), was prepared according to the published recommendations using deionised water under room temperature. A plastic cup (11.5 cm (L) × 8.5 cm (W) × 2 cm (D)) which was used to place Gloriosa flower stem, filled with approximately 25 ml of the SVS for wet storage. Experiment was repeated twice.

The effects of storage temperatures at 4 ºC and 13 ºC and durations of 7, 10 and 14 days of storage on flower quality and longevity were studied. The “wet” stored inflorescence stems were placed in above plastic cups with their stem bases in SVS floral preservative solution. Then they were enclosed in polythene bags to reduce water loss during the cold storage period. “Dry” stored inflorescences were enclosed in polythene bags. After cold storage they were unwrapped, weighed, re-cut and placed in same vase solution, SVS. Flowers were held at room temperature (20 ± 5 ºC) and ambient indoor fluorescent light conditions (15 µmol·m$^{-2}$·s$^{-1}$) 12 h day/night and evaluated daily. Holding solution was added when needed during the vase period. Each treatment had 3 replicates.

The fresh weights of these flowers were measured before cold storage, after storage and during vase period of all experiments. Flower quality was evaluated regularly, observations of noticeable changes in quality were recorded. The changes in colour of flower petals and leaves during flower vase life were recorded. It was measured on randomly selected individuals (3 petals and 3 leaves per flower stem) with a chroma meter (Minolta, CR-200b; Minolta, Germany). Colour was recorded using the CIE - $L^*a*b^*$ uniform colour surface (Clydesdale, 1978). Results were expressed in $L^*$ indicating lightness, $a^*$ (red-green) and $b^*$ (yellow-blue) indicating Gloriosa petal and leaf colour intensity and calculated hue angle ($h^*$ - arctan $b^*$/a*) and chroma ($C^*-(a^{*2}+b^{*2})^{1/2}$) which relate to human visual perception (McGuire, 1992).

Three fully-grown leaves on the terminal shoot of each flower stem of all treatments were randomly selected in each experiment for measuring basic chlorophyll fluorescence parameters with a portable chlorophyll fluorometer (MINI PAM, Walz, Effeltricht, Germany). Measurements were taken on the upper surface of the leaves through leaf clip, attached to the leaf blade (Björkman and Demmig, 1987; Larsson et al., 1999). The optimal quantum yield in photo system II is equal to $F_v/F_m = (F_m-F_0)/F_m$, where $F_m$ and $F_0$ denote maximum and minimum fluorescence in dark-adapted tissue, respectively (Schreiber and Bilger, 1993). $F_v$ was calculated using the above equation.

Statistical analysis was undertaken using SPSS version 11 (Chicago, USA, 1996). Data were presented as mean ± SD. Where appropriate a post hoc test was undertaken to rank the means. The Pearson method was used to calculate correlation among variables at a significance level of 0.05.

RESULTS AND DISCUSSION

Fresh Weight and Vase life

Fresh weight and vase life of cut Gloriosa stems were markedly affected by increasing cold storage temperature, duration and the packing system (Table 1). The highest fresh weight gain (36.16 %) during storage was observed in flowers under “wet” stored at 4 ºC for 7 days compared to other treatments. “Wet” stored flowers increased
their fresh weight during storage period under both temperatures (4 °C and 13 °C) in varying amounts (Fig. 1). However, “dry” stored flowers showed significantly lower weight in storage as well as in vase period (Fig. 2).

Interestingly, flowers kept under “wet” storage at 4 °C for 7 days, showed increase of fresh weight up to day 3 of vase life and then started to decrease till the end of vase life. However, flowers of all other treatments (4 °C - 10 d, 13 °C - 7 d and 10 d) continuously decreased their actual fresh weight over the vase period. Our study showed that flowers under “dry” storage at both 13 °C and 4 °C temperature decreased in fresh weight significantly, even when kept in the vase solution during vase period (Table 1). “Wet” storage for longer period (> 10 d) was detrimental for the better performances during vase period (data not shown). Post-storage performance of the Gloriosa flowers depended on storage temperature, duration and storing method. We observed that for lower storage period (< 5 d) for both “wet” and “dry”, Gloriosa flowers kept in 4 °C did not show significant differences for the following fresh weight changes, colour and chlorophyll fluorescence changes (data not shown). However, the above-mentioned quality parameters were affected by increased temperature and increase in durations of the storage period. Mor (1989) found that low water content in storage performed better during vase period and thereby recommending to keep rose flowers “dry” in the storage. However, Gloriosa cut flowers showed better performances during vase period, when they were kept in “wet” storage.

Pre-storage pulsing of cut flowers with sucrose or a floral preservative has already been reported by Halevy and Mayak (1979) to improve flower-keeping quality after cold storage by manipulating cell membrane integrity and reducing their sensitivity to ethylene during cold storage. Here we continuously treated flowers with SVS during the storage period for “wet” storage condition and it markedly affected flower quality during post-storage period. According to our experimental results, flowers stored “wet” at 4 °C for 7 days gave significantly the highest vase life (12.61 d) than any other treatment. Vase life values decreased significantly after day 7 depending on “wet” and “dry” storage at both temperatures (Table 1).

**Chlorophyll Fluorescence**

Chlorophyll fluorescence was used as sensible indicators of stress and ‘vitality’ during senescence. Gloriosa flower leaves kept at 4 °C in “wet” storage for 7 days showed higher chlorophyll fluorescence values ($F_o$, $F_m$ and $F_v$) up to third day of the vase period and then values declined. However, $F_o$, $F_m$, $F_v$ and yield values tended to show higher values in end of vase life than initial values. Results showed better performances of Gloriosa flower stems kept at 4 °C (wet storage - 7 d) in vase period till end of vase life. In contrast, stems kept at 13 °C showed a lower photosynthetic active yield (0.73) in end of vase life. Flower stems stored at 4 °C showed the highest yield value (0.76) by the end of vase life (Table 3). A higher initial chlorophyll fluorescence ($F_o$) of flower stems kept in 13 °C did not increase fluorescence yield during vase period. Stems stored under wet and dry storage at 4 °C and 13 °C for 10 days resulted continuous decline of all parameters (data not shown).

Our experiment clearly showed the relationship of changes in chlorophyll fluorescence parameters with the storage temperature. Keeping flower stems at low temperature resulted in lower yield at the beginning as ‘anabolic’ rates were reduced in cold storage. When cut stems were placed in a floral solution after cold storage, they absorbed nutrients and water from the floral solution and were influenced to maintain physiological and ‘metabolic’ activities of the cut stem. Above same procedure promoted to continue Gloriosa flower development and to show better performances during vase period. In contrast, flowers kept at higher temperatures (13 °C) had higher chlorophyll fluorescence at the beginning of the experiment because they were able to maintain higher ‘catabolic’ rates in storage. In comparison to flowers kept at 4 °C they did not show significantly higher performances in the vase and resulted to senesce within short period. We assume higher ‘metabolic’ activities in storage period and thus decline of energy
reserves and earlier membrane distinction as induced senescence during vase period. Our results conclude that chlorophyll fluorescence can be used to evaluate the ‘flower quality’ of *Gloriosa* kept in the cold storage. Our results show that the chlorophyll fluorescence is a good indicator of identifying *Gloriosa* flower senescence symptoms in the vase period after keeping flowers in cold storage. Floral preservatives and tap water do not significantly affect changes of chlorophyll fluorescence for a shorter period, in the case of flowers placed in vase solutions.

**Flower Colour**

Chroma values (colour intensity parameters) of flowers and leaves kept in “wet” vials at both temperatures (13 °C and 4 °C) showed a similar pattern, having a low value at senescence. The petal colour intensity declined throughout the vase period even when stems were placed in a floral solution. However, a slight variation was observed in stems kept at 4 °C (-4.98 %) than stems kept at 13 °C (-7.10 %). Petal hue angle of stems kept at both treatments increased (4 % at 4 °C, 2.5 % at 13 °C) during vase period indicating an improvement of red hue of petals (Table 3). Clear visual colour change was observed after cold storage, indicating that higher colour intensity and red hue of flowers kept at 4 °C than flowers kept at 13 °C. Petal colour changed approximately 3 days after placing in floral solutions, from its original red-orange to a red-brown shade of flowers kept at 13 °C for 10 days (data not shown). In contrast, petal colour of stems kept at 4 °C for 7 days remained unchanged in first 3 days. By the end of vase life, flowers kept at 13 °C showed discolouration of the petal and brown patches on petals, while flowers stored at 4 °C showed only a very slight lightening of their original red-yellow/orange colour. There were no significant differences in petal hue angle between initial and final values of stems stored in both temperatures.

**Leaf Colour**

The chroma value of *Gloriosa* stems kept at 4 °C and 13 °C, increased during vase period however, the differences were not significant (Table 3). A higher chroma (colour intensity) variation (20.35 %) of stems kept at 13 °C in “wet” storage than stems placed at 4 °C under “wet” storage (5.91 %) was observed. There is a positive correlation with the visual observations. Although, vase life was shorter, leaves of the stems placed at 13 °C showed a bright but darker colour at senescence. Physiological activities usually decline in cold storage and therefore, stems kept at 4 °C showed chlorophyll degradation even in vase period. Leaf hue of stems kept at 4 °C showed a negative value (-3.6 %) at the end of vase life (Table 3). In contrast, hue of leaves kept at 13 °C was given a significantly higher value (-0.98) at termination than the value observed in early stage of the vase life (-1.04). Experimental results and visual observations indicate that flower colour was affected by increasing cold storage temperature. Low temperature in the storage resulted to increase leaf colour intensity and hue angle of flower stems except stems kept at 4 °C.

**CONCLUSION**

Our results support short-term cold storage up to 5-7 days as a possible method to maintain keeping quality of *Gloriosa* inflorescences in the postharvest chain. Experiments showed that adding a floral preservative positively affected flower quality and longevity during the cold storage and enhanced performances in the vase period. The physiological mechanisms of beneficial effect of ‘wet’ storage on physiological and metabolic performances of cold stored *Gloriosa* flowers remains to be analyzed in details. According to measured quality attributes, we suggest to store cut *Gloriosa* flower stems under “wet” storage with a selected floral preservative solution at 4 °C less than 7 days.

**ACKNOWLEDGEMENTS**

The authors thank the Institute of Fruit Growing and Horticulture, University of Natural Resources and Applied Life Sciences, Vienna, Austria for financial support and Austrian Development Cooperation (Ministry of Foreign Affairs, Austria) for a
postgraduate scholarship.

**Literature Cited**


**Tables**

Table 1. Effect of storage temperature on fresh weight in cold storage and vase life of “wet” and “dry” stored cut Gloriosa inflorescences. Data are means ± SE (n = 3).

<table>
<thead>
<tr>
<th>Storage condition</th>
<th>Wet storage</th>
<th></th>
<th>Dry storage</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh weight and % weight change during storage period</td>
<td>Vase life (d)</td>
<td>Fresh weight and % weight change during storage period</td>
<td>Vase life (d)</td>
</tr>
<tr>
<td>4 °C - 7 d</td>
<td>Initial 16.01 ± 0.54 (36.16 %) Final 21.80 ± 0.13</td>
<td>12.61 ± 0.26</td>
<td>Initial 14.97 ± 0.42 (-5.01 %) Final 14.22 ± 0.25</td>
<td>8.06 ± 0.51</td>
</tr>
<tr>
<td>13 °C - 7 d</td>
<td>Initial 15.35 ± 0.10 (8.08 %) Final 16.59 ± 0.07</td>
<td>10.33 ± 0.32</td>
<td>Initial 15.92 ± 0.27 (-13.00 %) Final 13.85 ± 0.38</td>
<td>6.48 ± 0.65</td>
</tr>
<tr>
<td>4 °C - 10 d</td>
<td>Initial 15.72 ± 1.10 (9.80 %) Final 17.26 ± 0.86</td>
<td>8.27 ± 0.88</td>
<td>Initial 15.32 ± 0.56 (-10.18 %) Final 13.76 ± 0.21</td>
<td>5.10 ± 0.46</td>
</tr>
<tr>
<td>13 °C 10 d</td>
<td>Initial 15.25 ± 1.24 (5.18 %) Final 16.04 ± 1.18</td>
<td>6.54 ± 0.53</td>
<td>Initial 15.63 ± 0.31 (-27.06 %) Final 11.40 ± 0.74</td>
<td>5.94 ± 0.74</td>
</tr>
</tbody>
</table>

459
Table 2. Effect of storage temperature and method for variation of chlorophyll fluorescence parameters during vase period. Data are means ± SE of three replications.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>$F_0$</th>
<th>$F_m$</th>
<th>$F_v$ ($F_m - F_0$)</th>
<th>Yield ($F_v/F_m$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 °C wet 7 d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>481.10 ± 9.97</td>
<td>1781.60 ± 49.01</td>
<td>1300.50 ± 39.52</td>
<td>0.73 ± 0.006</td>
</tr>
<tr>
<td>Day 3</td>
<td>564.66 ± 7.17</td>
<td>2314.84 ± 42.37</td>
<td>1750.18 ± 30.14</td>
<td>0.76 ± 0.004</td>
</tr>
<tr>
<td>End of vase life</td>
<td>547.83 ± 7.48</td>
<td>2293.40 ± 39.25</td>
<td>1745.57 ± 35.10</td>
<td>0.76 ± 0.003</td>
</tr>
<tr>
<td>13 °C wet 7 d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>578.23 ± 9.12</td>
<td>2296.67 ± 39.22</td>
<td>1718.44 ± 31.99</td>
<td>0.75 ± 0.002</td>
</tr>
<tr>
<td>Day 3</td>
<td>608.07 ± 9.71</td>
<td>2145.93 ± 39.15</td>
<td>1537.86 ± 29.89</td>
<td>0.72 ± 0.001</td>
</tr>
<tr>
<td>End of vase life</td>
<td>591.13 ± 6.89</td>
<td>2189.87 ± 35.16</td>
<td>1598.73 ± 29.35</td>
<td>0.73 ± 0.002</td>
</tr>
</tbody>
</table>

Table 3. Effect of temperature for colour change during vase period of *Gloriosa* stored for 7 d under “wet” cold storage. Data are means ± SD (n = 3).

<table>
<thead>
<tr>
<th>Plant part</th>
<th>Chroma Initial</th>
<th>Chroma End of vase</th>
<th>% Chroma change</th>
<th>Hue angle Initial</th>
<th>Hue angle End of vase</th>
<th>% hue change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowers (4 °C)</td>
<td>33.91 ± 4.32</td>
<td>32.22 ± 5.62</td>
<td>-4.98</td>
<td>0.50 ± 0.12</td>
<td>0.52 ± 0.09</td>
<td>4.00</td>
</tr>
<tr>
<td>Leaves (4 °C)</td>
<td>17.42 ± 3.29</td>
<td>18.45 ± 4.48</td>
<td>5.91</td>
<td>-0.98 ± 0.03</td>
<td>-1.01 ± 0.08</td>
<td>-3.60</td>
</tr>
<tr>
<td>Flowers (13 °C)</td>
<td>27.19 ± 5.36</td>
<td>25.26 ± 7.76</td>
<td>-7.10</td>
<td>0.40 ± 0.09</td>
<td>0.41 ± 0.15</td>
<td>2.50</td>
</tr>
<tr>
<td>Leaves (13 °C)</td>
<td>18.67 ± 5.67</td>
<td>22.47 ± 4.46</td>
<td>20.35</td>
<td>-1.04 ± 0.03</td>
<td>-0.98 ± 0.36</td>
<td>5.77</td>
</tr>
</tbody>
</table>

Figures

Fig. 1. Fresh weight (Wt 1 - Initial weight, Wt 2 - weight after 2 d, Wt 3 - weight after 4 d & Wt 4 - End of vase life) changes of “wet” stored inflorescences in different storage conditions. Data are presented as means (n = 5) with SE.
Fig. 2. Changes of fresh weight of “dry” stored inflorescences during vase period (FW 1 - Initial weight, FW 2 - weight after 2 d, FW 3 - End of vase life). Data are presented as means (n = 3) with SE.